APPENDIX I.

USGCRP Member Agencies

This section summarizes the principal focus areas related to global change research for each USGCRP member agency.

DEPARTMENT OF AGRICULTURE

The U.S. Department of Agriculture's (USDA) global change research program includes contributions from the Agricultural Research Service (ARS), the National Institute of Food and Agriculture (NIFA), the Forest Service (USDA-FS), Natural Resources Conservation Service (NRCS), National Agricultural Statistics Service (NASS), and Economic Research Service (ERS). These USDA entities ensure sustained food security for the Nation and the world. They maintain and enhance the health of U.S. forests and natural resources while identifying risks to agricultural production ranging from temperature and precipitation changes to the changing biology of pests, invasive species, and diseases.

USDA supports greenhouse gas inventories and conducts assessments and projections of climate-change impacts on the natural and economic systems associated with agricultural production. USDA develops cultivars, cropping systems, and management practices to improve drought tolerance and build resilience to climate variability. USDA promotes integration of USGCRP research findings into farm and natural resource management and helps build resiliency to climate change by developing and deploying decision support. USDA maintains critical long-term data collection and observation networks, including the Long-Term Agro-ecosystem Research (LTAR) Network, the Snowpack Telemetry (SNOTEL) network, the Soil Climate Analysis Network (SCAN), the National Resources Inventory (NRI), and the Forest Inventory and Assessment (FIA). USDA has instituted seven Regional Hubs for Risk Adaptation and Mitigation to Climate Change to develop and deliver science-based region-specific information and technology. Finally, USDA engages in communication, outreach, and education through multiple forums, including its vast network of agricultural extension services.

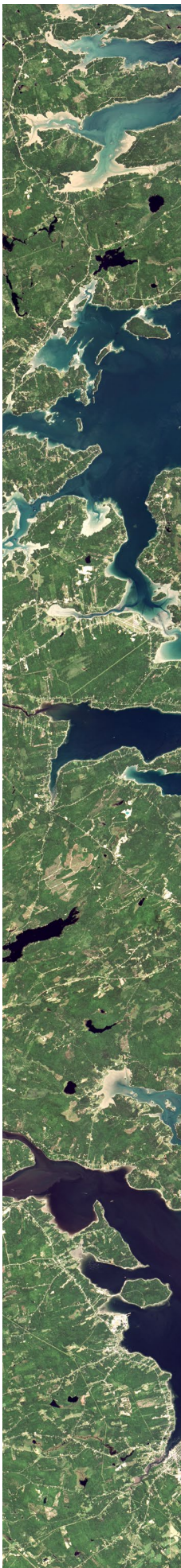
DEPARTMENT OF COMMERCE

The National Oceanic and Atmospheric Administration (NOAA) and the National Institute of Standards and Technology (NIST) comprise the Department of Commerce's (DOC's) participation in USGCRP.

NOAA's strategic climate goal is "an informed society anticipating and responding to climate and its impacts." NOAA's overall objective is to provide decision makers with a predictive understanding of the climate and to communicate climate information so that people can make more informed decisions in their lives, businesses, and communities. These outcomes are pursued by implementing a global observing system, conducting research to understand climate processes, developing improved modeling capabilities, and developing and deploying climate educational programs and information services. NOAA aims to achieve its climate goal through the following strategic objectives:

- Improved scientific understanding of the changing climate system and its impacts;
- Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions;
- Mitigation and adaptation efforts supported by sustained, reliable, and timely climate services; and
- A climate-literate public that understands its vulnerabilities to a changing climate and makes informed decisions.

NIST works with other Federal agencies to develop or extend internationally accepted traceable measurement standards, methodologies, and technologies that enhance measurement capabilities for greenhouse gas emission inventories and measurements critical to advancing climate science research. NIST provides measurements and standards that support accurate, comparable, and reliable climate observ-



-ations and provides calibrations and special tests to improve the accuracy of a wide range of instruments and techniques used in climate research and monitoring.

DEPARTMENT OF DEFENSE

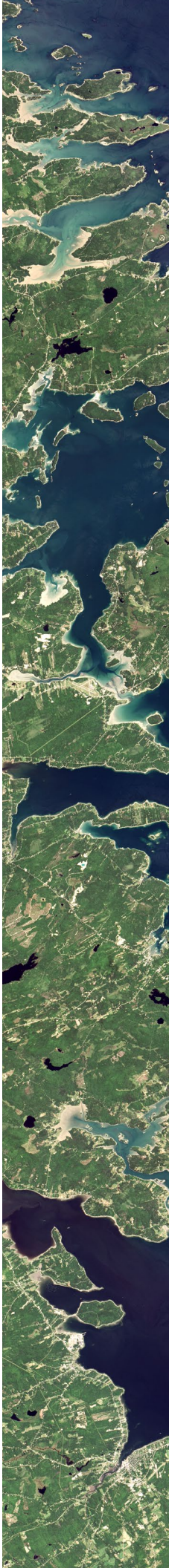
The Department of Defense (DOD)—while not supporting a formal mission dedicated to global change research—is developing policies and plans to manage and respond to the effects of climate change on DOD missions, assets, and the operational environment. Various research agencies within DOD sponsor and undertake basic research activities that concurrently satisfy both national security requirements as well as the strategic goals of USGCRP. These include the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), and the Defense Advanced Research Projects Agency (DARPA). When applicable, the research activities of these agencies are coordinated with other Federally sponsored research via USGCRP and other entities.

Because the performance of DOD systems and platforms are influenced by environmental conditions, understanding the variability of the Earth's environment and the potential for change is of great interest to the Department. DOD is responsible for the environmental stewardship of hundreds of installations throughout the United States and must continue incorporating geostrategic and operational energy considerations into force planning, requirements development, and acquisition processes. DOD relies on the Strategic Environmental Research and Development Program (SERDP), a joint effort among DOD, DOE, and EPA, to develop climate change assessment tools and to identify the environmental variables that must be forecast with sufficient lead time to facilitate appropriate adaptive responses. Each service agency within DOD incorporates the potential impact of global change into their long-range strategic plans. For example, the Navy's Task Force Climate Change (TFCC) assists in the development of science-based recommendations, plans, and actions to adapt to climate change. The USACE Engineer Research and Development Center (ERDC) Cold Regions Research and Engineering Laboratory (CRREL) also actively investigates the impacts of climate trends for DOD and other agencies. The CRREL research program responds to the needs of the military, but much of the research also benefits the civilian sector and is funded by non-military customers such as NSF, NOAA, NASA, DOE, and state governments.

DEPARTMENT OF ENERGY

The Department of Energy's (DOE) Office of Science supports fundamental research to address key uncertainties in regional to global-scale Earth system change arising from the interactions and interdependencies of the atmospheric, terrestrial, subsurface, cryospheric, oceanic, and human-energy components of the Earth system. DOE's research strives to understand and anticipate how environmental and compounding stressors behave within a non-linear system and how these stressors, in turn, can influence the robustness and resilience of U.S. energy infrastructure. Particular emphasis also is placed on understanding how natural and human-derived factors contribute to variabilities and trends spanning local to global scales and extending from seasonal to multi-decadal time horizons. Supporting its major role in Earth system prediction, DOE advances long-term field experiments and best-in-class computing, exploiting major user facilities; develops modeling and simulation tools; conducts process and systems level research; incorporates model and data analytics and uncertainty characterization; and carries out archiving and management of extensive observed and model-generated data sets for use by the research community.

There are three areas of DOE research that contribute to the Department's efforts to advance the science of Earth system change: (a) Atmospheric System Research (science of aerosols, clouds, and radiative transfer); (b) Terrestrial Ecosystem Science (role of terrestrial ecosystems and coupled biogeochemical cycles); and (c) advanced modeling that combines development, simulation and analysis. DOE maintains its own suite of advanced modeling platforms, including the Energy Exascale Earth System Model (E3SM), which uses DOE's advanced high performance computers; DOE also collaborates with NSF to support the widely-used Community Earth System Model. DOE supports methods to obtain, evaluate, and analyze



regional climate information; explores and simulates multi-scale, multisector dynamics in context of global and regional changes and influences; and analyzes and distributes large Earth System Model output through the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the Earth System Grid. The Department supports the Atmospheric Radiation Measurement Climate Research Facility, a scientific user facility based on three permanent observatories and four mobile platforms that provides the research community with unmatched measurements permitting the most detailed high-resolution, three-dimensional documentation of evolving cloud, aerosol, and precipitation characteristics in climate-sensitive sites around the world.

DOE also conducts related applied research through its policy and energy offices. The research and analyses undertaken by these offices often requires the development and application of companion models to those used in Office of Science, e.g. models of energy systems and infrastructures; economics; technology impact; and risk-assessment. The applied offices also maintain and update data sets to explore such topics as electric grid stability, water availability for energy production, and siting of energy infrastructures.

DEPARTMENT OF HEALTH AND HUMAN SERVICES

The U.S. Department of Health and Human Services (HHS) supports a broad portfolio of research and decision support initiatives related to environmental health and the health effects of global climate change, primarily through the National Institutes of Health (NIH) and the Centers for Disease Control and Prevention (CDC). Research focuses on the need to better understand the vulnerabilities of individuals and communities to climate-related changes in health risks such as heat-related morbidity and mortality, respiratory effects of air contaminants affected by climate change, changes in transmission of infectious diseases, and impacts in the aftermath of severe weather events, among many others. Research efforts also seek to assess the effectiveness of various public health adaptation strategies to reduce climate vulnerability, as well as the potential health effects of interventions to reduce GHG emissions.

Specifically, HHS supports USGCRP by conducting fundamental and applied research on linkages between climate variability and change and health, translating scientific advances into decision support tools for public health professionals, conducting ongoing monitoring and surveillance of climate-related health outcomes, and engaging the public health community in two-way communication about climate change.

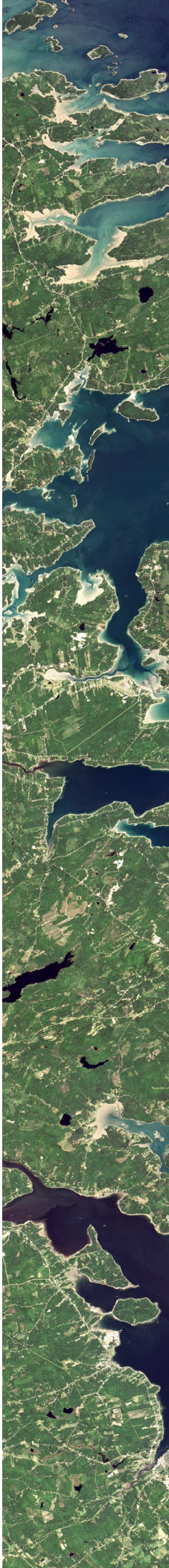
DEPARTMENT OF INTERIOR

The U.S. Geological Survey (USGS) conducts global change research for the Department of the Interior (DOI) and constitutes DOI's formal participation in USGCRP.

USGS scientists work with other agencies to provide policy makers and resource managers with scientifically valid information and an understanding of global change and its impacts with the ultimate goal of helping the Nation understand, adapt to, and mitigate global change.

Specifically, the USGS Land Resources Mission Area supports research to understand processes controlling Earth system responses to global change and understand impacts of climate and land-cover change on natural resources. The USGS Land Change Science and National Land Imaging programs (such as the Landsat satellite mission and the National Land Cover Database) provide data that is used to assess changes in land use, land cover, ecosystems, and water resources resulting from the interactions between human activities and natural systems. The science products and datasets from these programs are essential for DOI's biological carbon sequestration project (LandCarbon), which is conducting quantitative studies of carbon storage and GHG flux in the Nation's ecosystems.

USGS also leads the regional DOI Climate Adaptation Science Centers that provide science and technical support to region-based partners dealing with the impacts of climate change on fish, wildlife, and their habitats.



DEPARTMENT OF STATE

The Department of State (DOS) contributes to the Intergovernmental Panel on Climate Change (IPCC), which assesses scientific, technical, and socioeconomic information relevant to the understanding of climate change, its potential impacts, and options for adaptation and mitigation. DOS, with the assistance of USGCRP, coordinates U.S. reviews of IPCC reports and U.S. author nominations and represents the U.S. at Panel meetings. DOS also works with other agencies in promoting international cooperation in a range of bilateral and multilateral science initiatives and partnerships.

DEPARTMENT OF TRANSPORTATION

The Department of Transportation (DOT) conducts research to examine potential climate-change impacts on transportation, methods for increasing transportation efficiency, and methods for reducing emissions that contribute to climate change. DOT's Center for Climate Change and Environmental Forecasting coordinates transportation and climate-change research, policies, and actions within DOT and promotes comprehensive approaches to reduce emissions, address climate-change impacts, and develop adaptation strategies. DOT also contributes directly to USGCRP's National Climate Assessment through focused research such as the Center's Gulf Coast Studies. The Gulf Coast Phase 2 study, completed in FY 2015, developed tools to assist transportation agencies in performing climate change and extreme weather vulnerability assessments and build resilience.

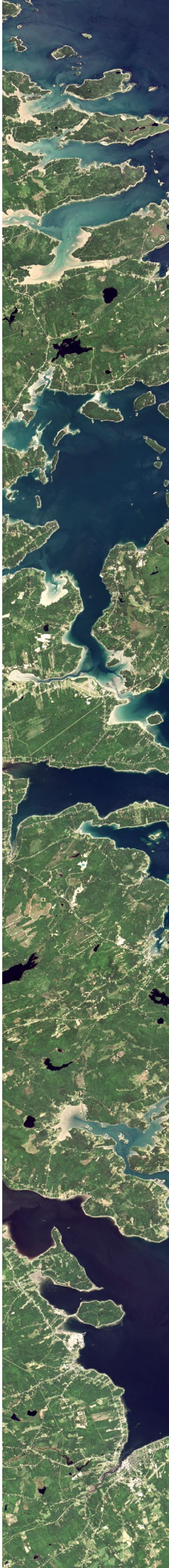
DOT works closely with USGCRP and its participating agencies to identify and address key scientific gaps regarding aviation climate impacts and to inform mitigation solutions. Other DOT initiatives to address climate change and improve the sustainability of the U.S. transportation sector follow:

- The Federal Highway Administration (FHWA) and other DOT agencies are undertaking climate impact and adaptation studies (including vulnerability and risk assessments), working with science agencies to develop regional climate data and projections, conducting methodological research, supporting pilot programs, and providing assistance to transportation stakeholders including state and local agencies.

- The Federal Aviation Administration (FAA) manages the Continuous Lower Energy, Emissions, and Noise (CLEEN) program as a government–industry consortium to develop technologies for energy efficiency, noise and emissions reduction, and sustainable alternative jet fuel. FAA also participates in the Commercial Aviation Alternative Fuels Initiative (CAAFI), a public–private coalition to encourage the development of sustainable alternative jet fuel.

ENVIRONMENTAL PROTECTION AGENCY

The core purpose of the Environmental Protection Agency's (EPA's) global change research program is to develop scientific information that supports policy makers, stakeholders, and society at large as they respond to climate change and associated impacts on human health, ecosystems, and socioeconomic systems. EPA's research is driven by the Agency's mission and statutory requirements, and includes: (1) improving scientific understanding of global change effects on air quality, water quality, ecosystems, and human health in the context of other stressors; (2) assessing and defining adaptation options to effectively prepare for and respond to global change risks, increase resilience of human and natural systems, and promote their sustainability; and (3) developing an understanding of the potential environmental and human health impacts of GHG emission reduction technologies and approaches to inform sustainable mitigation solutions. EPA Program Offices and Regions leverage this research to support mitigation and adaptation decisions and to inform communication with external stakeholders and the public.



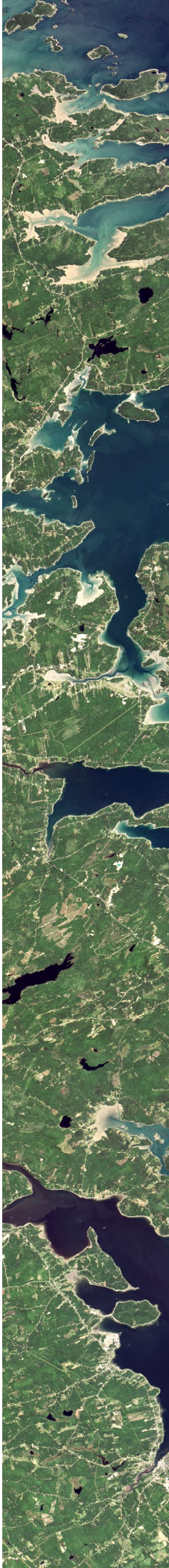
EPA relies on USGCRP to develop high-quality scientific models, data, and assessments to advance understanding about physical, chemical, and biological changes to the global environment and their relation to drivers of global climate change. Satellite and other observational efforts conducted by USGCRP agencies are crucial to supporting EPA's efforts to understand how land use change, population change, climate change, and other global changes are affecting ecosystems, and the services they provide. EPA's global change research applies and extends these results using regional and local air quality, hydrology, and sea level rise models to better understand the impacts of climate change to specific human health and ecosystem endpoints in ways that enable local, regional, and national decision makers to develop and implement strategies to protect human health and the environment. In turn, EPA's research provides USGCRP agencies with information and understanding about the connections between global change and impacts at local, regional, and national scales, as well as how mitigation and adaptation actions may influence global changes.

EPA's research informs approaches to prepare for, adapt to, and minimize the impacts of climate change, including extreme weather events, wildfire, and rising sea levels, and their impacts on human health and well-being and social and economic systems. Other EPA activities apply long-term datasets, analytical tools, and models to examine and communicate observed climate change indicators and project impacts and economic damages associated with global mitigation scenarios.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA's global change activities have four integrated foci: satellite observations, research and analysis, applications, and technology development. Satellites provide critical global atmosphere, ocean, land, sea ice, and ecosystem measurements. NASA's 21 on-orbit missions (as of September 2018) measure numerous variables required to enhance understanding of Earth interactions. In 2018, NASA launched the Gravity Recovery and Climate Experiment Follow On (GRACE-FO) dual-satellite mission with its German partner GFZ (German Research Centre for Geosciences) to restart the record from the 2002–2017 GRACE satellite mission. GRACE-FO will continue the work of tracking Earth's water movement to monitor changes in underground water storage, the amount of water in large lakes and rivers, soil moisture, ice sheets and glaciers, and sea level caused by the addition of water to the ocean. NASA also launched the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) instrument to the International Space Station (ISS) in 2018, which will measure the temperature of plants and use that information to better understand how much water plants need and how they respond to stress. Additional launches planned in 2018 are the Ice, Cloud, and land Elevation Satellite (ICESat-2), which will allow scientists to measure the elevation of ice sheets, glaciers, and sea ice in unprecedented detail, and the Global Ecosystem Dynamics Investigation (GEDI) to the ISS, which will measure the structure of Earth's tropical and temperate forests in high resolution and three dimensions. NASA's Earth Science Technology program also deployed several small (U-Class) satellites (also known as CubeSats) from the International Space Station in 2018 as part of its InSpace Validation of Earth Science Technologies program. In 2018, NASA selected two additional missions as part of its Earth Venture–Instrument series: 1) the Polar Radiant Energy in the Far Infrared Experiment (PREFIRE), which will fly a pair of small CubeSat satellites to probe a little-studied portion of the radiant energy emitted by Earth for clues about Arctic warming, sea ice loss, and ice-sheet melting ; and 2) the Earth Surface Mineral Dust Source Investigation (EMIT), which is a sensor that will be mounted to the exterior of the ISS to determine the mineral composition of natural sources that produce dust aerosols around the world.

NASA's program advances observing technology and leads to new and enhanced space-based observation and information systems. The Earth science research program explores interactions among the major components of the Earth system—continents, oceans, atmosphere, ice, and life—to distinguish natural from human-induced causes of change and to understand and predict the consequences of change. NASA makes significant investments to assure the quality and integration of data



through calibration and validation efforts that include satellite, surface, and airborne measurements, as well as data intercomparisons. NASA also carries out observationally driven modeling projects that include data assimilation, reanalysis, process representation, initialization, and verification. Significant airborne and shipborne campaigns took place during 2018, including the combined NASA-NSF Export Processes in the Ocean from Remote Sensing (EXPORTS) ship-based campaign in the Pacific Ocean and continued observations in Northwest Canada and Alaska through the Arctic-Boreal Vulnerability Experiment (ABoVE) campaign. Applications projects extend the societal benefits of NASA's research, technology, and spaceflight programs to the broader U.S. public through the development and transition of user-defined tools for decision support, and are focused on such areas as water resources, health/air quality, and ecological forecasting. The Earth science technology program funds, develops and demonstrates a broad range of cutting-edge technologies – from new instruments and components to advanced modeling and information systems- to enable new capabilities, and reduces the cost, risk, and/or development times for Earth science instruments.

NATIONAL SCIENCE FOUNDATION

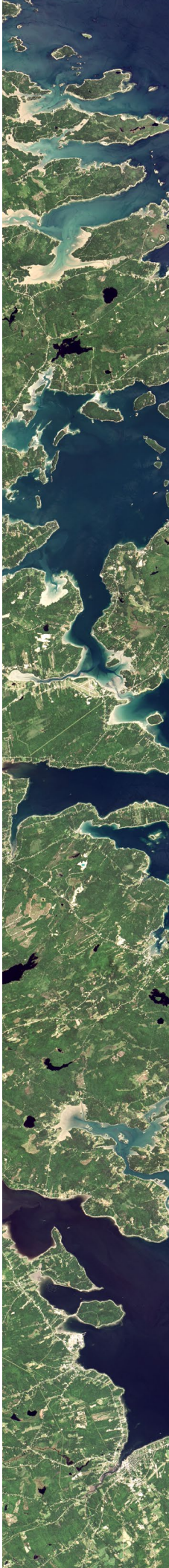
The National Science Foundation (NSF) addresses global change issues through investments that advance frontiers of knowledge, provide state-of-the-art instrumentation and facilities, develop new analytical methods, and enable cross-disciplinary collaborations while also cultivating a diverse, highly trained workforce and developing educational resources. In particular, NSF global change programs support the research and related activities to advance fundamental understanding of physical, chemical, biological, and human systems and the interactions among them. The programs encourage interdisciplinary approaches to studying Earth system processes and the consequences of change, including how humans respond to changing environments and the impacts on ecosystems and the essential services they provide. NSF programs promote the development and enhancement of models to improve understanding of integrated Earth system processes and to advance predictive capability. NSF also supports fundamental research on the processes used by organizations and decision makers to identify and evaluate policies for mitigation, adaptation, and other responses to the challenge of a changing and variable environment. Long-term, continuous, and consistent observational records are essential for testing hypotheses quantitatively and are thus a cornerstone of global change research. NSF supports a variety of research observing networks that complement, and are dependent on, the climate monitoring systems maintained by its sister agencies.

NSF regularly collaborates with other USGCRP agencies to provide support for a range of multi-disciplinary research projects and is actively engaged in a number of international partnerships.

SMITHSONIAN INSTITUTE

Within the Smithsonian Institution (SI), global change research is primarily conducted at the National Air and Space Museum, the National Museum of Natural History, the National Zoological Park, the Smithsonian Astrophysical Observatory, the Smithsonian Environmental Research Center, and the Smithsonian Tropical Research Institute. Research is organized around themes of atmospheric processes, ecosystem dynamics, observ¬ing natural and anthropogenic environmental change on multiple time scales, and defining longer-term climate proxies present in the historical artifacts and records of the museums as well as in the geologic record. Most of these units participate in the Smithsonian's Global Earth Observatories, examining the dynamics of forests (ForestGEO, formerly SIGEO) and coastal marine habitats (MarineGEO) over decadal time frames.

The Smithsonian also brings together researchers from around the Institution to focus on joint programs ranging from estimating volcanic emissions to ocean acidification measurement. Smithsonian paleontological research documents and interprets the history of terrestrial and marine ecosystems from 400 million years ago to the present. Other scientists study the impacts of historical environmental change on the ecology and evolution of organisms, including hu¬mans. Archaeobiologists examine the impact of early humans resulting from



their domestication of plants and animals, creating the initial human impacts on planetary ecosystems.

These activities are joined by related efforts in the areas of history and art, such as the Center for Folklife and Cultural History, the National Museum of the American Indian, the Anacostia Community Museum, and the Cooper Hewitt Museum of Design to examine human responses to global change, within communities, reflected in art and culture, food, and music. Finally, Smithsonian outreach and education expands our scientific and social understanding of processes of change and represents them in exhibits and programs, including at the history and art museums of the Smithsonian. USGCRP funding enables the Smithsonian to leverage private funds for additional research and education programs on these topics.

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

The U.S. Agency for International Development (USAID) carries out climate change and development work in four main areas: energy, sustainable landscapes, climate resilience, and climate risk management. USAID supports global research and analysis and partners bilaterally with dozens of countries to build capacity, address governance, and create the legal and regulatory environment needed to address climate change and development. This work is integral to helping countries pursue economic growth, stability, and self-reliance.

Energy: USAID helps partner countries build strong energy sectors that can attract private investment and power global economic and social development. USAID's efforts support least-cost modern energy solutions. In many countries, renewable energy is now the least-cost solution that maximizes development impact.

Sustainable landscapes: USAID supports research on estimating and accounting for land-based carbon stocks and greenhouse gas fluxes, and on governance and finance in the land sector, all with a focus on developing countries. USAID also supports partner countries in meeting their commitments to reduce land-based greenhouse gas emissions, often through activities that promote conservation, restoration, and sustainable use of forests, agriculture, and other lands. By improving landscape management, USAID helps to curb destruction and degradation, improve livelihoods, and increase resilience.

Climate resilience: USAID works with partner countries to build climate resilience and disaster preparedness to weather and climate-related shocks and stresses such as droughts, floods, and shifting rainfall patterns. Improved weather and climate information, informed land use planning, and smart infrastructure design are some ways communities can prepare for these risks and avoid setbacks. Thinking ahead and proactively managing risks help sustain livelihoods and maintain critical services, reducing the need for costly disaster response.

Climate risk management (CRM): CRM is an internal USAID practice to assess, address and manage climate risk in new strategies, projects, and activities across USAID's development portfolio, safeguarding U.S. investments through informed decision-making.

With over seventy overseas missions, USAID enables decision makers to apply high-quality climate information to their decision making and enables countries to accelerate their transition to climate resilient, sustainable economic development. USAID achieves these objectives through direct programming and integration of climate change adaptation and mitigation activities into the broader development portfolio.

USAID leverages scientific and technical resources from across the U.S. Government, private sector partners, and nongovernmental organizations and science institutes to develop and implement low-emissions development strategies, creating policy frameworks for market-based approaches to emission reduction and energy sector reform, promoting sustainable management of agricultural lands and forests, protecting biodiversity, and mainstreaming adaptation into development activities in countries most at risk to advance resilient and sustainable development.